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Efficiency improvement from multiple perspectives: An application to Japanese banking industry

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ABSTRACT

The current study focuses on efficiency improvement for banking systems from multiple perspectives, which have different definitions of input/output about various attributes of a banking system. In this research we utilize data envelopment analysis (DEA) and Nash bargaining game (NBG) theory to improve inefficient banks in order to: (1) Make the inefficient bank be the state of Pareto Optimality for multiple perspectives, which can avoid discontentment of some perspectives. (2) Improve a bank by changing its attributes and provide various improving schemes for decision makers. A numerical case study of Japanese banks is also given to show the results of equilibrium solution from multiple perspectives.

1. Introduction

The concept of data envelopment analysis (DEA) was first introduced by Farrell [1], and developed by Charnes et al. [1,2] who bring forward an epochal CCR model to consummate DEA theory. Being a popular nonparametric methodology to evaluate and compare the efficiencies of peer entities, viz. "decision making units" (DMUs), DEA is widely used in a variety of research fields, including management and finance, as well as nonprofit organizations. The main use of a DMU is transforming inputs into outputs. DEA estimates efficiency scores of DMUs by their relative locations with respect to the efficient frontier, which is composed by all efficient DMUs in the system.

In traditional DEA research, efficiency analysis is based on a *single perspective*, namely, a unique input/output classification scheme about the attributes of DMU. Generally the classification scheme used to determine whether an attribute should be considered as an input or an output is determined by the perspective before efficiency analysis. If the value of an attribute is considered the more the better from the perspective, it is determined as an output. On the contrary, it is considered to be an input. In the case of *multiple perspectives* an attribute may play different roles from different perspectives. For example, in the present study the DMU is a complicated banking system in which the same attributes may be interpreted differently based on the multiple perspectives of various stakeholders. One attribute that is considered to be an input from one perspective but may be considered to be an output from another perspective is "profitability" of a bank. Profitability of a bank is usually considered to be an input from the perspective of the customer, because higher profitability of banks is achieved at their expense in the form of higher fees and charges [3]. However, from the perspective of management, profitability may be defined as an output, since higher profitability leads to higher salary and bonuses for them.

Given this, the efficiency score of DMU_o estimated by the CCR model varies with different perspectives, as they would use different input/output classifications. In the case of a single perspective, the method to effectively improve DMU_o (assume DMU_o is not efficient) is to move DMU_o to a point located on the efficient frontier, which is the linear combination of the points in its reference set. Basically the movement of DMU_o can be summarized as either decreasing inputs while keeping the *status quo* for outputs (for input-oriented CCR model) or increasing outputs and keeping inputs (for output-oriented CCR model) [4]. But for the case of multiple perspectives, as an attribute considered to be input from one perspective may be considered to be output from another, it is difficult to determine whether to increase or decrease its value in order to improve DMU_o. The main challenge is figuring out how to measure the efficiency score of DMU_o in the case of multiple perspectives, and how to adjust its attributes in order to satisfy multiple perspectives to the maximum extent.

As multiple perspectives have different input/output classifications which cause different preferences in adjusting attributes of DMU_o, the opinions of adjusting attributes of DMU_o from these perspectives are always conflictive. For example, the management may expect to benefit from the higher profitability, but the

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customer may insist on decreasing profitability. Also they have different opinions in adjusting the attributes of credit quality and efficiency of a bank. If we also consider other perspectives like shareholder, employee and so on, the situation becomes much more complicated. Thus we need an appropriate method to determine how to adjust the attributes of DMU_o in such a conflictive case under multiple perspectives. Nash bargaining game (NBG) [5,6] is a popular method in dealing with equilibrium solutions to problems involving multiple players. In the current study, each perspective of a stakeholder is defined as a player. We use NBG (1) to determine the appropriate value for each attribute, namely, whether to increase or decrease an attribute of DMU_o and to what extent to improve an attribute; (2) to improve DMU_o in different directions which can provide multiple improving schemes for decision maker. The proposed game mode of NBG is cooperative. Multiple perspectives negotiate for a higher efficiency score in fixing the appropriate value of an attribute of DMU_o. There exist various other approaches, like weighted sum or weighted mean of efficiency scores of multiple perspectives. But these methods cannot ensure the equilibrium for multiple perspectives, and the results may invoke discontentment of some perspectives. For a complicated banking system, it is not an advisable method to sacrifice the profit of some perspectives.

The remainder of this article is structured as follows. In Section 2, we briefly review the previous studies related to our research. In Section 3, we introduce the main process of efficiency improvement in the case of multiple perspectives. A numerical case study of 65 Japanese banks is given to show the actual application of the method in Section 4. The paper ends with conclusion and a discussion about the results.

2. Previous literature: the single perspective vs. multiple perspectives

Numerous studies focusing on efficiency analysis for the banking industry have employed the concept of DEA [7–17]. These studies show meaningful findings which are useful for bank management or branch managers. The problem of multiple perspectives was previously studied by Sarrico et al. [18], where each type of students was referred to as one perspective. Different student types defined universities' attributes as either inputs or outputs depending on their age, ability, aptitude, future job prospects, etc. Different types of students may give different evaluations for the same university. A related study by Dyson et al. [19–22], discussed the problem of classifying DEA attributes by introducing desirable input versus undesirable output, which means more input is better or, analogously less output is preferred. They also discussed the modeling and computational complexity in the research.

In the research of Bougnol et al. [23], in which they conducted an investigation into the Memphis I-40 public project, perspective was referred to as constituency. Constituencies stand for individuals living in the area relevant to a project. 64 constituencies listed had different designations of attributes (nine in all) to input or output depending on their positions. 26 projects were evaluated by 64 constituencies in order to compare the efficiencies of these projects. In the research of Garcia-Cestona et al. [24] they proposed a DEA model to evaluate Spanish savings banks with multiple goals depending on their different ownership structures. Their study indicates that each type of ownership structures has different goal priorities and efficiency levels. Another relevant use of the concept of multiple perspectives appeared in the research of Avkiran [3], which evaluated the efficiency of Chinese banks by surveying multiple stakeholders such as customers, management, employees and regulators. Different stakeholders have different input/output classifications that lead to different efficiency evaluation for the same bank.

There are also some researches incorporating game theory into DEA models. Du et al. [25] and Liang et al. [26] proposed a two-stage network DEA model in which they view each stage as a player and the two-stage DEA model is a cooperative game model. The bargaining game dealt with the conflict between two stages which is caused by the intermediate measures. On the other hand, a model based on identical weight assignment is proposed in our former research to show a more objective evaluation based on an identical weight assignment scheme. The method changes the selection strategy of inputs and outputs for different perspectives and evaluates DMUs fairly which can balance the views of multiple perspectives. A meaningful result of efficiency evaluation for 20 Chinese banks is also shown in the paper to compare the overall efficiency scores of DMUs from multiple perspectives.

Most of the previous studies related to multiple perspectives focused on efficiency evaluation and comparison for DMUs, whereas no study deals with efficiency improvement for DMUs, which are not efficient for all perspectives. There are many differences between a single perspective and multiple perspectives in improving an inefficient DMU. The concept of "efficiency" or "inefficiency" is not appropriate for the case of multiple perspectives. All DMUs need improvement in the case of multiple perspectives except the DMUs located at the crossing points of all efficient frontiers (such DMUs are efficient for all perspectives.). On the other hand, in the case of single perspective, the linear combination of points in the reference set is still an efficient point, which can be set as the target to improve the inefficient DMU. Whereas in the case of multiple perspectives, the linear combination of efficient DMUs on one efficient facet may not still locate on the facet, thus it is impossible to find out a reference set to improve inefficient DMUs.

The current research is based on the efficiency evaluation by CCR model from multiple perspectives, for which we will give detailed description in Section 3.1. For the DMUs which are already efficient for all perspectives, there is no need to improve them. For the DMUs partially efficient for some perspectives, we attempt to improve their efficiency by looking at all attributes and identifying the most effective one as the way to improve DMUs.

3. Efficiency improvement based on multiple perspectives

3.1. Efficiency evaluation from multiple perspectives

As the precondition of efficiency improvement, efficiency evaluation is processed by CCR model. Consider a set of n DMUs to be analyzed, of which input and output vectors are represented by an $(m \times n)$ matrix $\boldsymbol{X}$ and an $(s \times n)$ output matrix $\boldsymbol{Y}$. The number of inputs and outputs are denoted by m and s respectively. Thus the efficiency score of DMU_o being evaluated is shown as follows:

$$\begin{aligned} &\max_{\mathbf{v},\mathbf{u}} \boldsymbol{u}\boldsymbol{y}_o \\ &\quad s.t.\ \boldsymbol{v}\boldsymbol{x}_o = 1 \\ &\qquad -\boldsymbol{v}\boldsymbol{X} + \boldsymbol{u}\boldsymbol{Y} \le 0 \\ &\qquad \boldsymbol{v} \ge 0,\ \boldsymbol{u} \ge 0 \end{aligned} \tag{1}$$

where $\boldsymbol{x}_o = (x_{1o}, x_{2o}, \ldots, x_{mo})^T$ and $\boldsymbol{y}_o = (y_{1o}, y_{2o}, \ldots, y_{so})^T$ are input and output vectors of DMU_o. Row vectors $\boldsymbol{v}$ and $\boldsymbol{u}$ denote the weights of inputs and outputs. The objective function in Eq. (1) captures the maximum weighted output of DMU_o under the constraint $\boldsymbol{v}\boldsymbol{x}_o = 1$. Eq. (1) is a traditional efficiency evaluation model for single perspective, where each attribute is specified as either an input or an output. For multiple perspectives, as different perspectives have different perceptions about input/